GOES-R AWG Land Team: ABI Land Surface Temperature Algorithm

June 8, 2010

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LST Product Team

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- **LST Product Team**
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  - *Robert Hale*
- Others
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  - » Wei Guo (Proxy data)
  - » Tong Zhu (Proxy data)

Outline

- Executive Summary
- Algorithm Description
- ADEB and IV&V Response Summary
- Requirements Specification Evolution
- Validation Strategy
- Validation Results
- Summary

Executive Summary

- The ABI Land Surface Temperature (LST) algorithm generates the baseline products of land surface skin temperatures in three ABI scan modes: Full Disk, Hemisphere, Mesoscale.
- Version 4 was installed and tested in the AIT framework; Code Unit Test Review (CUTR) was done in March 2010; version 5 was delivered in May 2010; ATBD (100%) is on track for a July delivery.
- Responses to comments from ADEB, IV&V, SE and Harris have been written and are reflected in the latest ATBD.
- Existing ground station data (US, Africa and Europe) have been used for validation; a GOES-SURFRAD data match-up procedure and tool has been developed; test run using the 10 weeks of MODIS data are successful.
- The retrieved product is within the specs.

Algorithm Description
-- Objective

- Provides state-of-the-art algorithm for producing LST values over the GOES-R observation domain, in three ABI scanning modes: Full Disk, CONUS, Mesoscale;
- Meets the GOES-R mission requirements specified for the LST product;
- Has good heritage, for generating LST climate data record;
- Simplicity for ease of implementation/maintenance, operational robustness, and potential for improvement.

Algorithm Description
-- Retrieval Strategy

- **LST retrieval will be performed**
  - » Land surface pixels only, including inland water
  - » For three ABI scan modes: Full Disk, Hemisphere, Mesoscale
  - » For “clear” and “probably clear” pixels only
  - » For day and night
- **Cloud detection**
  - » Uses ABI cloud mask
- **Correction for atmospheric absorption**
  - » Use brightness temperature difference between the split window channels
  - » Apply path correction term
  - » Stratify algorithm coefficients for different atmospheric conditions
- **Correction for surface emissivity variation**
  - » Apply explicit emissivity value in algorithm
  - » Use dynamic emissivity data
- **Quality control flags**
  - » Generate algorithm QC flags in addition to data and cloud QC flags

Algorithm Description
-- Overview

ADR Algorithm

At ADR, there were three alternative solutions under consideration

- » **Split Window Algorithms** (e.g., *Yu et al.,* 2007, 2008**)**
- » **NPOESS/VIIRS Approach** (*Sikorski et al.,* 2004)
- » **Dual split window *algorithm*** (e.g., *Sun & Pinker*, 2004)

CDR Algorithm

Split window algorithm selected

- » **Least sensitive to emissivity variation in the thermal bands**
- » **Avoids larger noise in the shortwave IR band**
- » **Fairly good atmospheric absorption correction**
- » **Good historical heritage (potential for climate data record)**
- » **Simple to implement**

Features

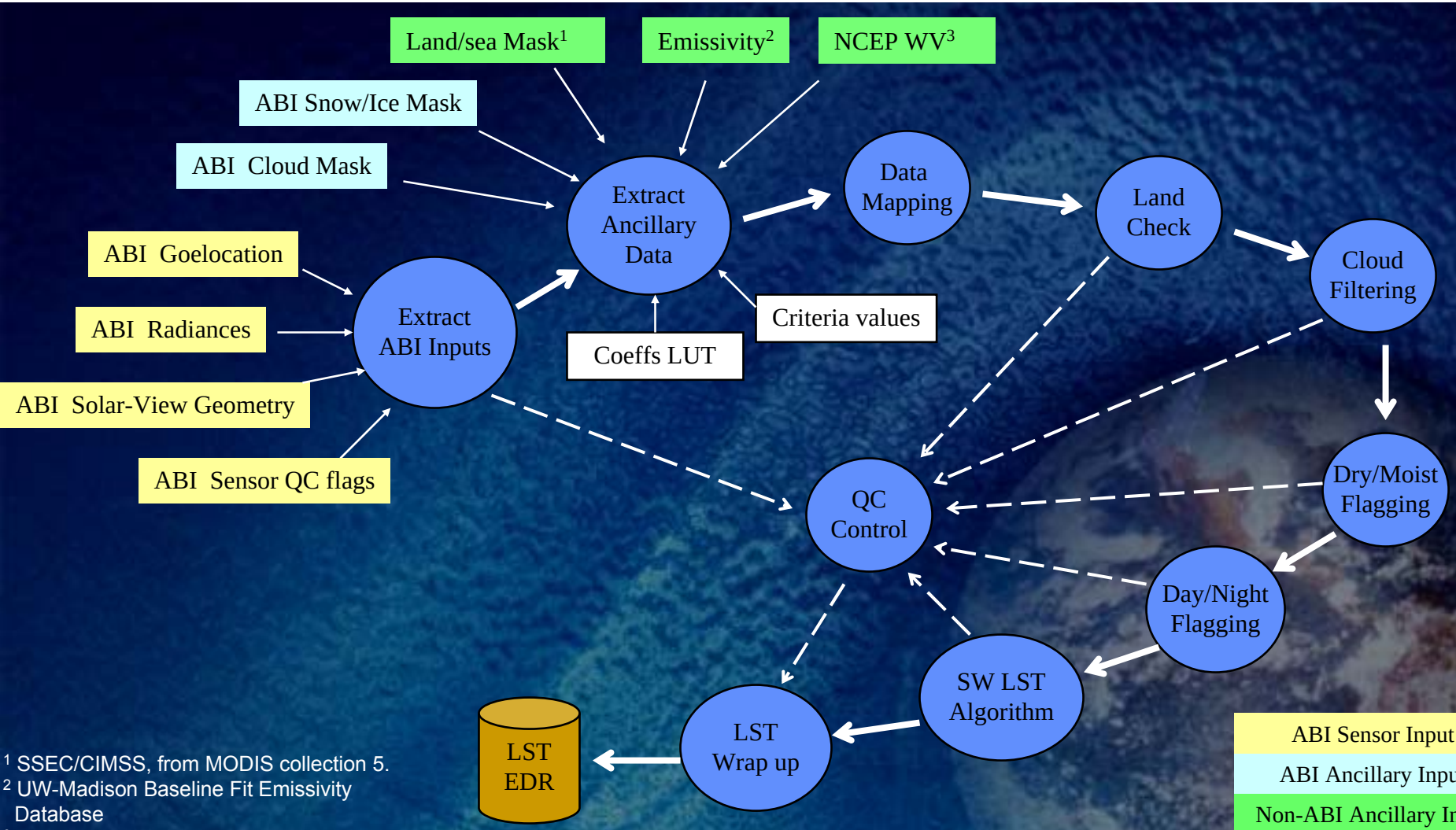
Explicit emissivity use selection

- » **Picks up emissivity variation of specific land surface types**
- » **Covers more land surface types (not limited)**
- » **Benefits from future emissivity product improvement**

Coefficient stratification by air mass conditions

- » **Better atmospheric correction under different conditions**

Algorithm Description
-- LST Processing Outline

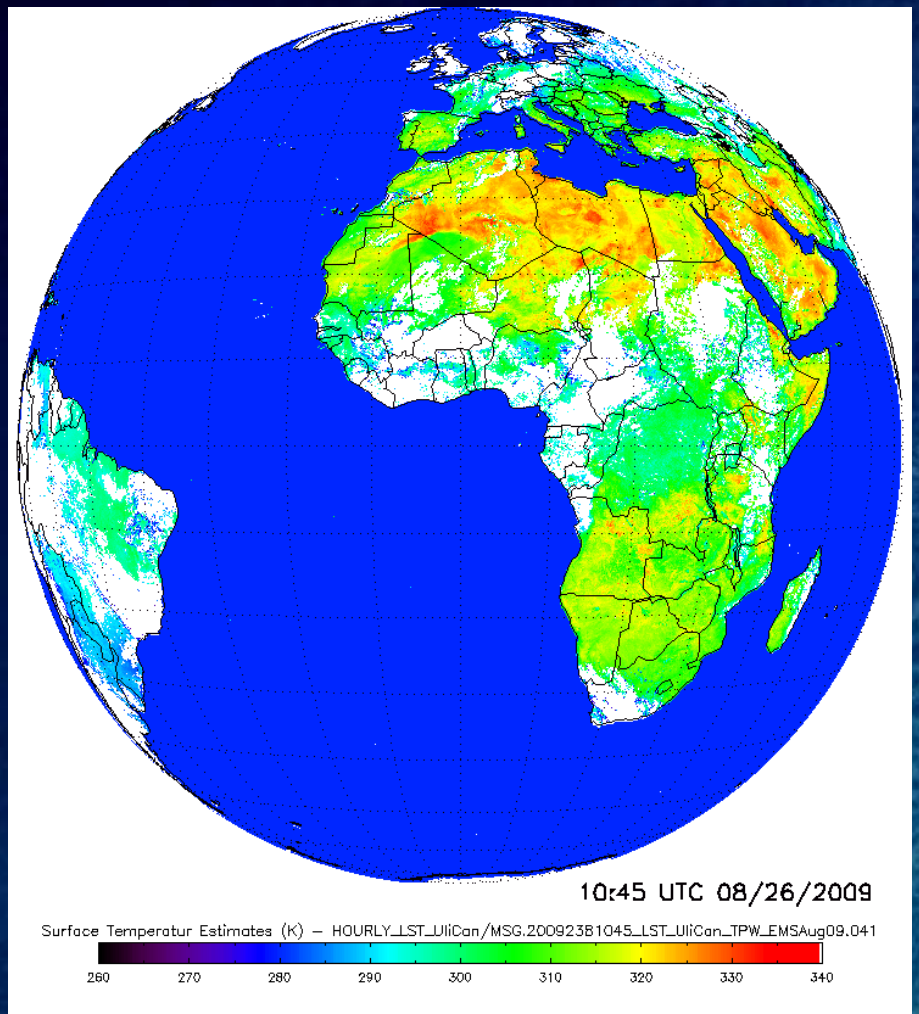


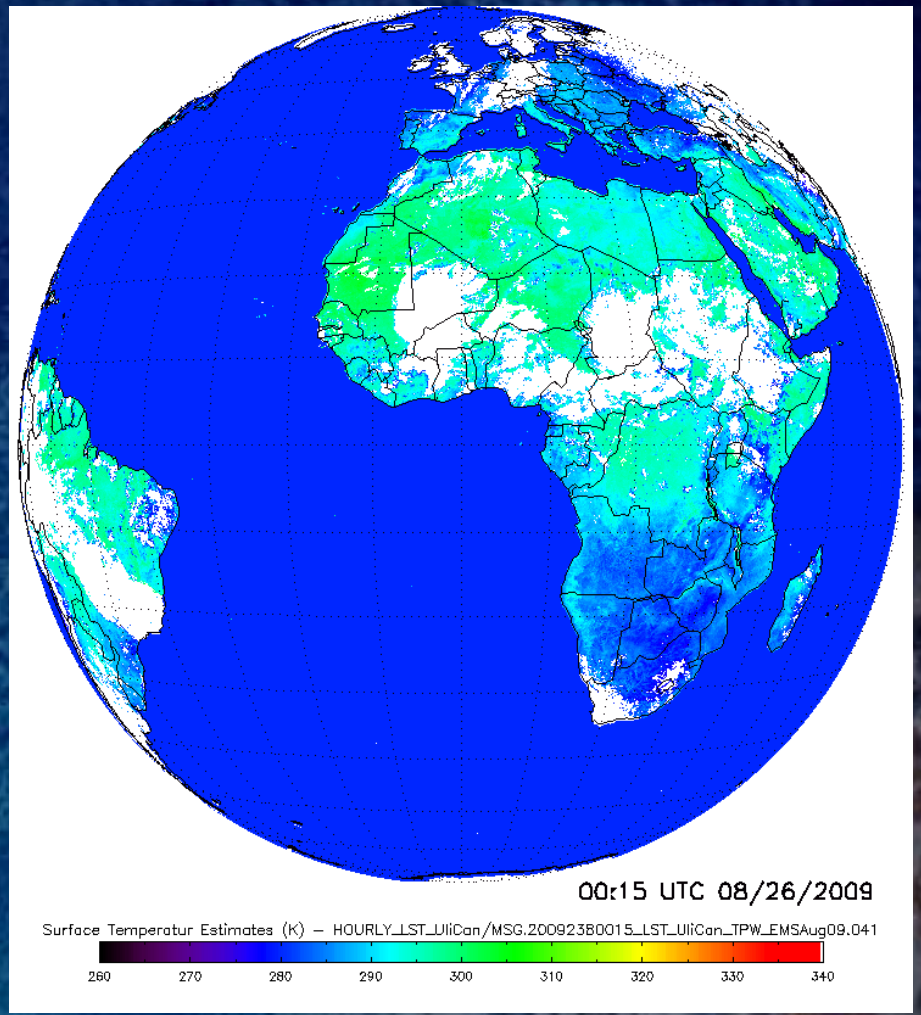
[1] SSEC/CIMSS, from MODIS collection 5.
[2] UW-Madison Baseline Fit Emissivity Database
[3] NCEP 6-hr forecast model

LST Processing Chain

Algorithm Description
-- Example LST Output

Sample LST images derived from MSG/SEVIRI data: a daily animation (right) on August 26th, 2009, and one scene (left) at 10:45 UTC time on the same day.





Algorithm Description
-- Changes from 80% to 100%

- Modifications are made in response to review comments from ADEB and IV&V.
- Requirements are updated
- New test and validation results are added
- Metadata output added.
- Quality flags are redefined, with new flags added.
- LST over inland water area is now generated.

ADEB and IV&V Response Summary

- All review comments are responded to in the ATBD (100%) submission (29 responses to comments are submitted).
- Significant evaluation and validation results are added.
- All 80% ATBD errors and clarification requests have been addressed.
- No feedback required for substantive modifications to the algorithm.

Requirements

Specification

Product	Accuracy	Precision	Range	Refresh Rate	Horizontal Resolution
Land Surface Temperature (CONUS)	2.5 K	2.3 K	213 ~ 330 K	60 min	2 km
Land Surface Temperature (Full Disk)	2.5 K	2.3 K	213 ~ 333 K	60 min	10 km
Land Surface Temperature (Mesoscale)	2.5 K	2.3 K	213 ~ 330 K	60 min	2 km

Requirements

Qualifiers

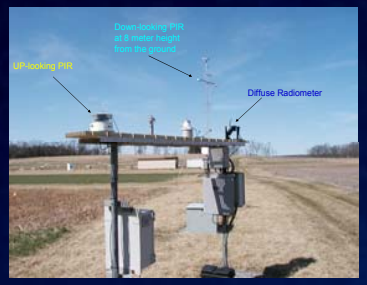
Product	Temporal Coverage	Product Extent	Cloud Cover Conditions	Product Statistics
Land Surface Temperature (CONUS)	Day and Night	LZA < 70	Clear Conditions associated with threshold accuracy	Over specified geographic area
Land Surface Temperature (Full Disk)	Day and Night	LZA < 70	Clear Conditions associated with threshold accuracy	Over specified geographic area
Land Surface Temperature (Mesoscale)	Day and Night	LZA < 70	Clear Conditions associated with threshold accuracy	Over specified geographic area

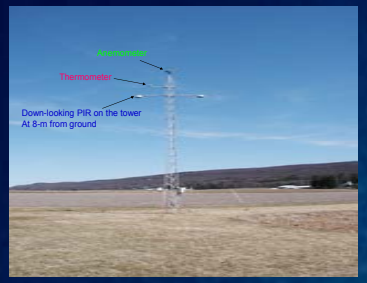
Validation Strategy

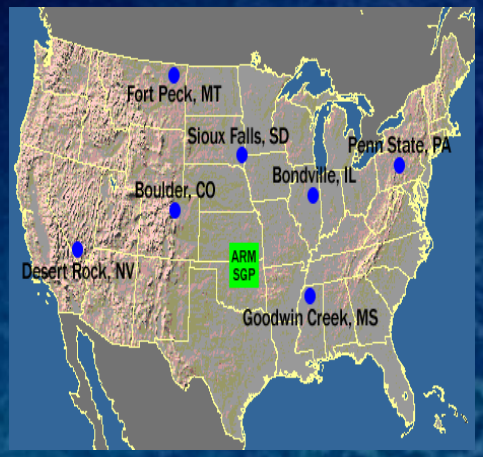
- Utilize existing ground station data
  - » Stations under GOES Imager coverage
  - » Stations under MSG/SEVIRI coverage
- Select proxy satellite data: Simulation, SEVIRI, GOES, MODIS
- Apply restrictive (additional) cloud filters for validation
- Collect sufficient data for statistical significance
- Multiple comparisons: satellite *vs* satellite, satellite *vs* ground station.
- 10-week MODIS swath data test

Validation Strategy
-- Match-up process

Satellite LST: Algorithms applied to GOES-8 Imager data
Ground LST: Derived from SURFRAD site measurements







GOES Imager data

Cloud filter

Algorithm: LST Calculation

Match-up and Comparison Statistics

Plots & Tables

SURFRAD radiance

Temperature :

$\Phi_{emit}=\Phi_{up}-(1-\varepsilon)\Phi_{down}$

$\Phi_{emit}=\varepsilon\sigma T^4$

Spectral Correction:

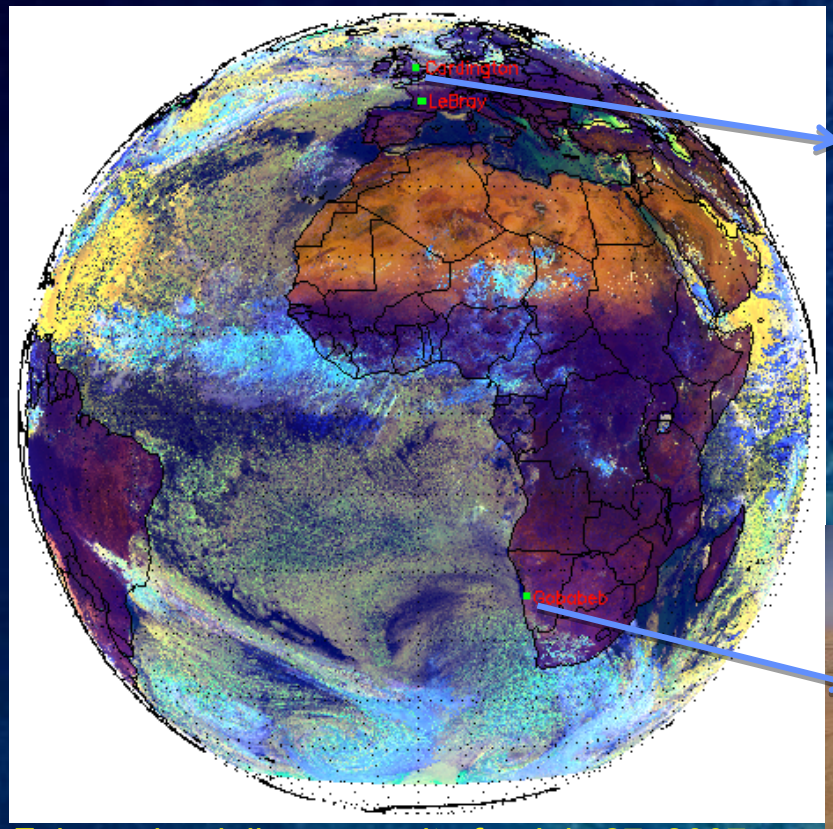
$T=T+dT^{pir} - dT^{\varepsilon}$

$dT^{pir}=(d\Phi_{\varepsilon}^{pir}/\Phi_{\varepsilon})(T/4)$

$dT_{\varepsilon}=(T/4)(d\varepsilon/\varepsilon)$

Validation Strategy
-- Data under SEVIRI

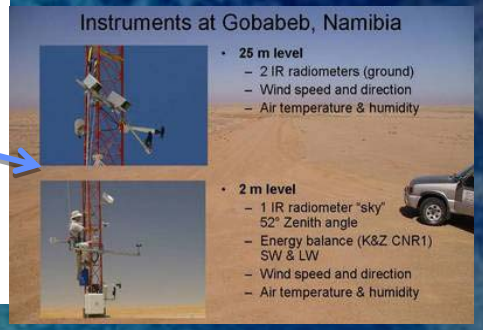
- One day field campaign at Le Bray, France
- More than two years' data for the UK Met Office Cardington dataset
- LST validation data for Gobabeb station, Namibia, Jan. 2008 to Oct. 2009.



False color daily composite for July 27, 2007.

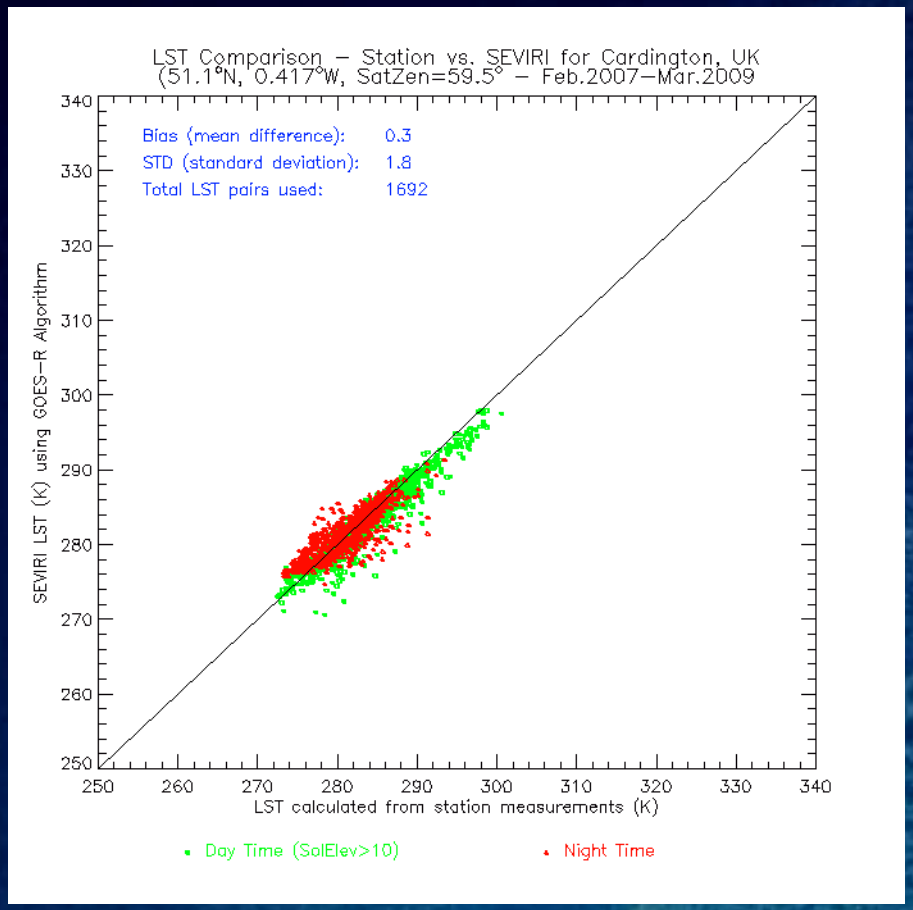
- Cardington, UK (52° 06' N, 00° 25' W)
  - Two Pyrogeometers for measuring the incoming and outgoing longwave irradiance with a spectral range of 4.5 to about 40 μm and have a field of view of 180° .
  - Download 1 minute measurement data through BADC restricted access: http://badc.nerc.ac.uk/browse/badc/ukmo-cardington

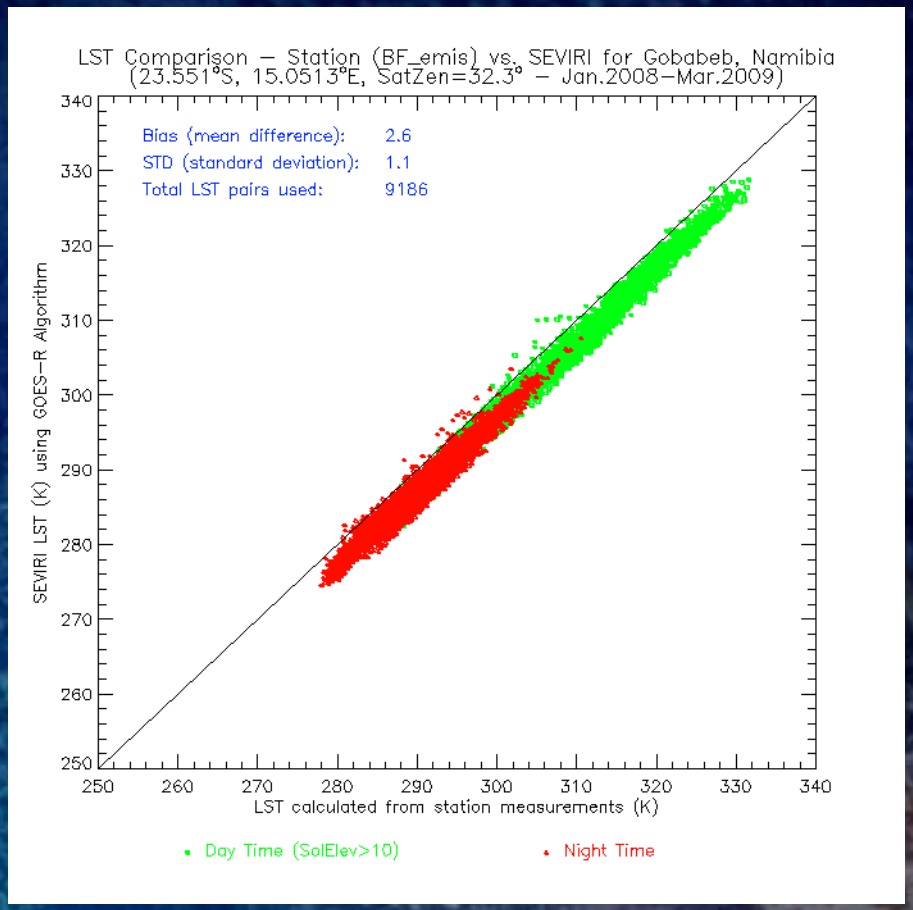
- Gobabeb Tower, (23° 33'S, 15° 03'E).



- Two down-looking radiometers measure at 25 m the upwelling radiance and a third radiometer at the 2 m level measures sky radiance.
- Courtesy of F. Olesen and F. Göttsche of KIT for the 1 minute brightness temperature data.

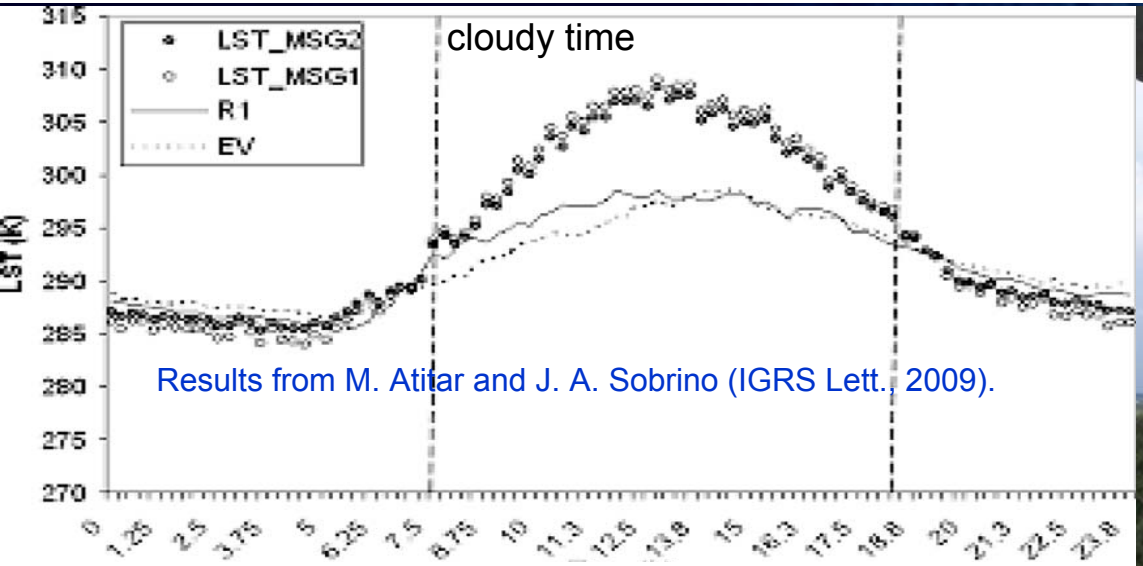
Validation Results
-- Stations under SEVIRI

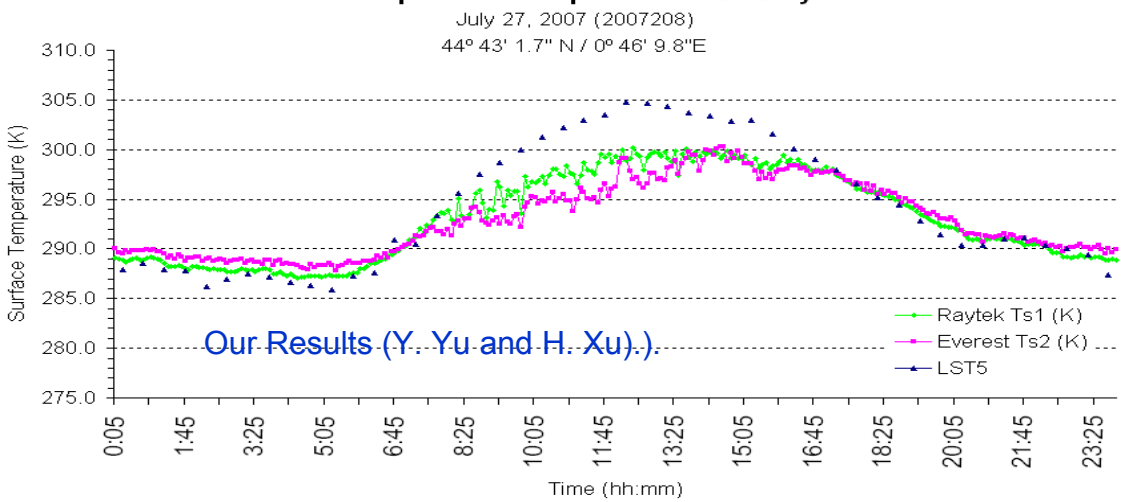




Scatter plots of LSTs derived from SEVIRI data vs. LSTs estimated from Cardington station (left) and Gobabeb station (right). Datasets are stratified for daytime (Green) and night time (red) atmospheric conditions

Validation Results
-- Field Campaign Data



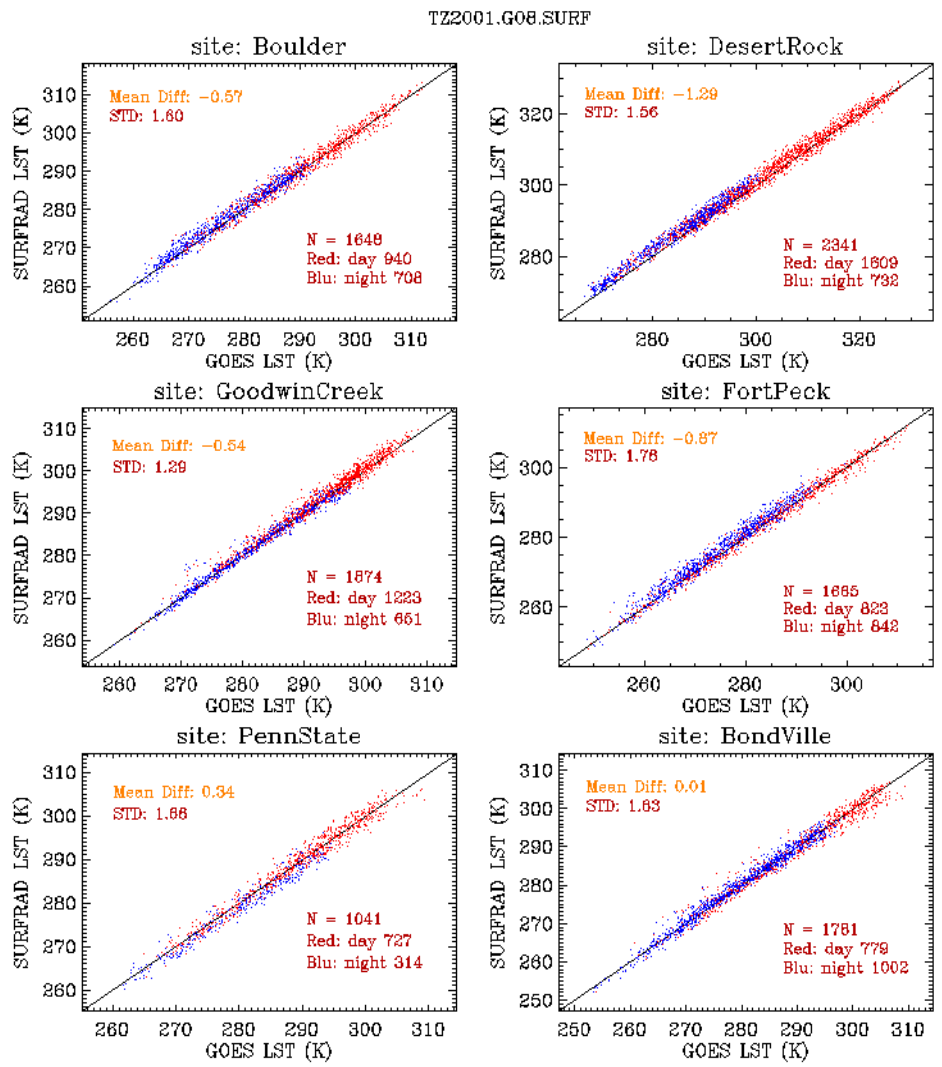


Courtesy by J.A. Sobrino

Field Data ---- a field campaign carried out in the zone of Bordeaux (44 ◦ 4301.7 N, 0 ◦ 4609.8 W), forest zone of Le Bray. LSTs were derived from two radiometers (Raytek (R) and Everest (Ev)) installed in a tower of 33-m altitude.

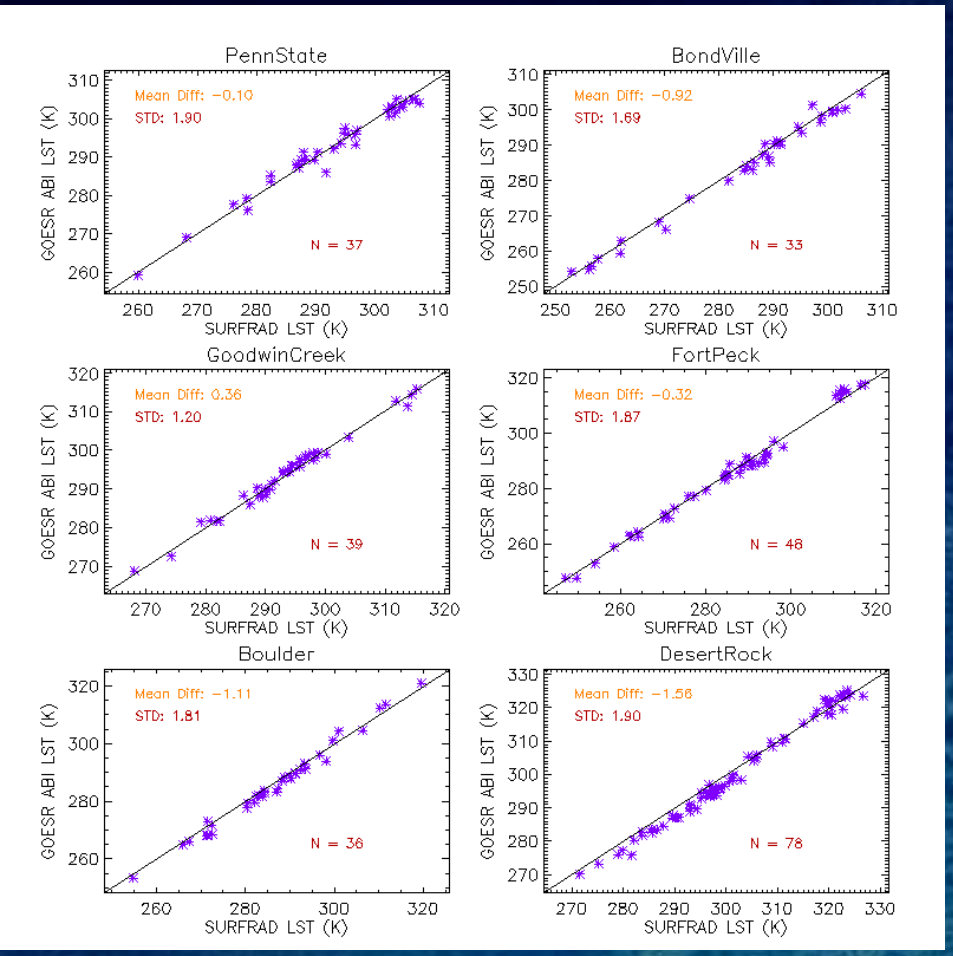
Validation Results
-- SURFRAD Stations

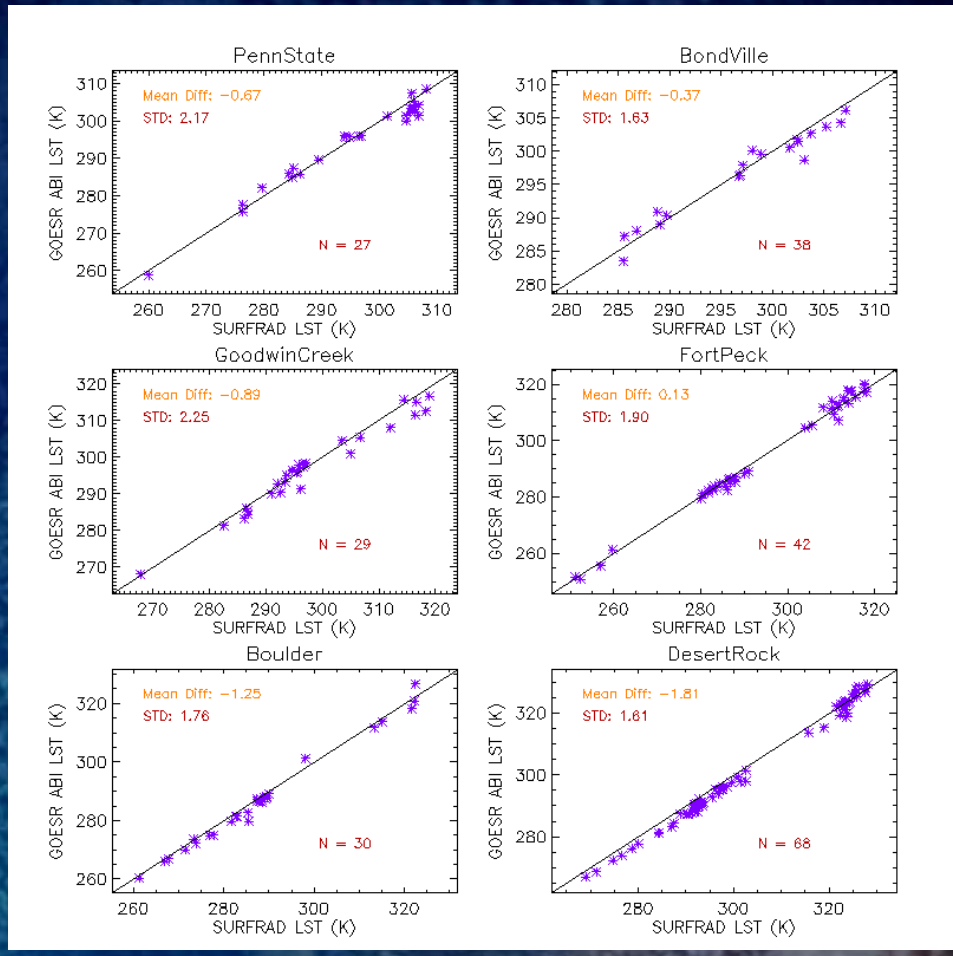
Month	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
1	48	17	55	64	107	107	58	48	100	67	100	51
2	43	30	38	38	73	57	55	34	41	54	64	48
3	0	0	51	71	94	62	93	79	41	63	123	34
4	94	18	39	80	81	34	62	61	81	57	139	35
5	71	22	27	59	127	65	75	83	82	45	168	75
6	50	26	82	102	82	51	65	50	86	64	187	60
7	6	4	91	77	40	8	27	38	40	43	173	74
8	43	30	129	113	41	38	82	137	56	45	107	52
9	115	57	95	108	124	49	79	110	116	85	189	98
10	103	38	62	95	184	39	90	79	74	58	115	61
11	114	34	43	129	146	70	64	53	116	53	131	88
12	40	38	67	66	124	71	73	70	107	74	113	56
Total	727	314	779	1002	1223	651	823	842	940	708	1609	732



Numbers (Table) and scatter plots of the match-up LSTs derived from GOES-8 Imager data vs. LSTs estimated from SURFRAD stations in year 2001. Data sets in plots are stratified for daytime (red) and night time (blue) atmospheric conditions.

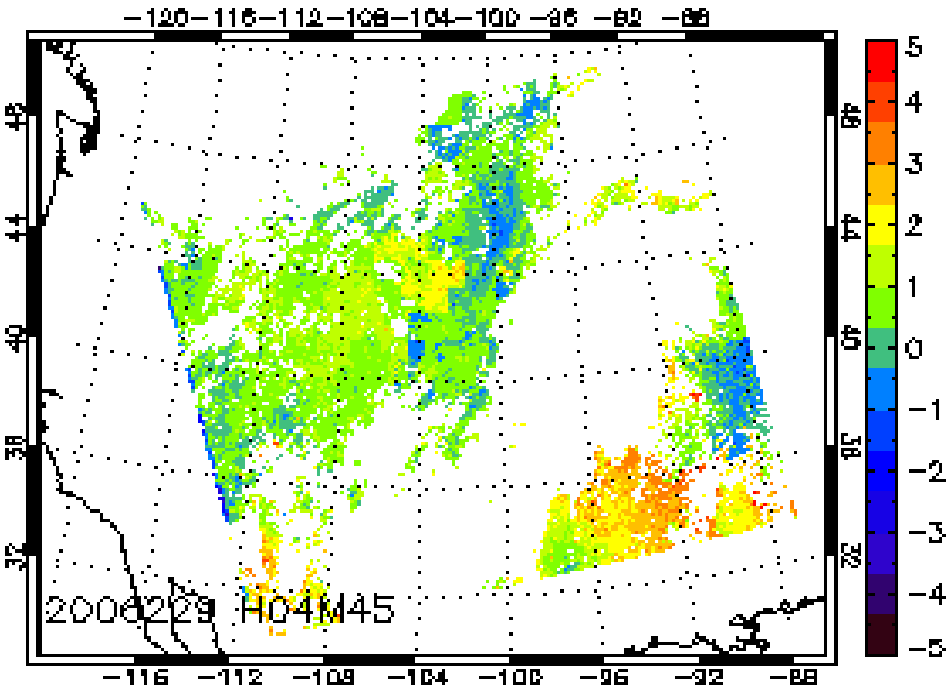
Validation Results
-- 10-week MODIS data





Scatter plots of GOES ABI LSTs with MODIS TERRA (left) and AQUA (right) proxy inputs vs. the Matched SURFRAD LSTs at each SURFRAD station.

Validation Results
-- 10-week MODIS data



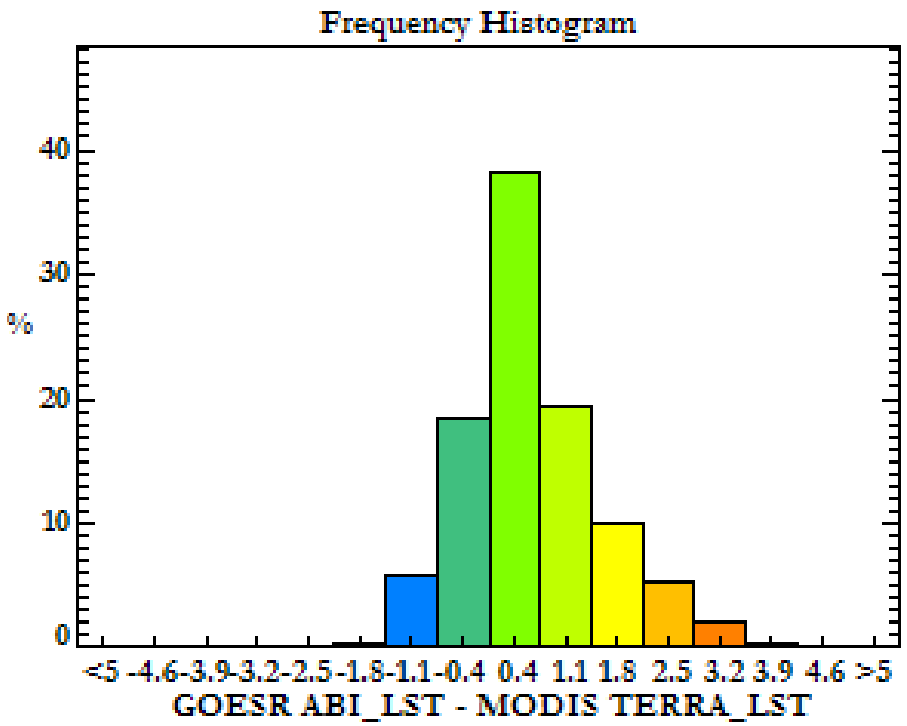


Image and histogram plot of LST difference between the proxy GOES-R LST and the MODIS LST. The data is sampled from MODIS Terra, on August 17, 2006

Validation Results Summary

Accuracy and precision (deg K) estimations of the ABI LSTs with the GOES-8 Imager data, over 6 SUFRAD stations.

Site	Overall			Day			Night		
	N	**Acc.**	**Prec.**	**N**	**Acc.**	**Prec.**	**N**	**Acc.**	**Prec.**
1	1041	0.34	1.66	727	0.01	1.56	314	1.09	1.66
2	1781	0.01	1.63	779	0.35	1.89	1002	-0.26	1.34
3	1874	-0.54	1.29	1223	-0.75	1.27	651	-0.14	1.24
4	1665	-0.87	1.76	823	-0.20	1.59	842	-1.52	1.68
5	1648	-0.57	1.60	940	-0.31	1.64	708	-0.90	1.49
6	2341	-1.29	1.56	1609	-1.00	1.56	732	-1.93	1.35

Accuracy and precision (deg K) estimations of the ABI LSTs with the 10-week MODIS (Terra & Aqua) data, over 6 SUFRAD stations.

Site	ABI LST – TERRA LST		ABI LST – SURFRAD LST	
	Acc.	**Prec.**	**Acc.**	**Prec.**
1	0.90	0.67	-0.10	1.90
2	0.53	0.90	-0.92	1.69
3	1.43	1.15	0.36	1.20
4	0.61	0.51	-0.32	1.87
5	0.53	0.67	-1.11	1.81
6	-0.19	0.35	-1.56	1.90

Site	ABI LST – AQUA LST		ABI LST – SURFRAD LST	
	Acc.	**Prec.**	**Acc.**	**Prec.**
1	0.50	0.81	-0.67	2.17
2	0.80	1.15	-0.37	1.63
3	1.72	1.64	-0.89	2.25
4	0.65	0.72	0.13	1.90
5	0.39	0.58	-1.25	1.76
6	-0.61	0.45	-1.81	1.61

Summary

- Split window algorithm is developed for producing GOES-R LST product.
- Version 5 is delivered and the 100% ATBD is coming.
- The LST product will meet the specifications.
- Validation method, dataset and tools are in development.